

tinet Kühne-Ruffini "spindles" from a muscle does not exclude the possession by it of sensorial end-organs, and of afferent nerve-fibres. This point is not without importance, because examination of various muscles has led me to the conclusion that the "spindle-organs" are absent from the following muscles:—From all the orbital eye-muscles, from the intrinsic muscles of the larynx (though Pacinian corpuscles occur in these as in various other muscles), from the intrinsic muscles of the tongue, and from the diaphragm. It is notable that all these muscles belong to that set which are innervated by nerve-fibres of rather smaller calibre (Gaskell) than those supplying the skeletal muscles generally, that is to say, are innervated by the non-ganglionated splanchnic efferent nerves of Gaskell.

"*On the Breaking-up of Fat in the Alimentary Canal under Normal Circumstances and in the Absence of the Pancreas.*" By VAUGHAN HARLEY, M.D., M.R.C.P., Professor of Pathological Chemistry, University College, London. Communicated by Professor HORSLEY, F.R.S.
Received March 18,—Read April 8, 1897.

(From the Department of Pathological Chemistry, University College, London.)

In a previous paper* I discussed the simple absorption of milk fat from the alimentary canal of dogs, and compared the results with a series of dogs in which the pancreas had been previously removed. Fasting dogs fed on milk absorbed no less than 21 to 46 per cent. of the total fat given in seven hours, while in those where the pancreas had been entirely removed some two days previously, there was, during that space of time, no evidence of any absorption whatever from the alimentary canal.

The fact that no marked absorption of fat occurred in dogs after the extirpation of the pancreas seems to confirm the old view that the pancreatic secretion was necessary for absorption.

This alleged action of pancreatic juice in preparing fat for its absorption from the alimentary canal, is usually supposed to be due to the secretion containing, firstly, a fat-splitting ferment, which, by breaking up part of the neutral fat into free fat acids and glycerine, leads to the first stage of emulsification; and, secondly, alkaline sodium carbonate, which combines with some of the freed fat acids to form a soap, thus rendering the emulsification of the fat a simple matter—as can easily be demonstrated in a test-tube—and at once facilitates its absorption through the intestinal walls.

* 'Journal of Physiology,' 1895, vol. 18, p. 1.



The manner in which altered or emulsified fat may traverse the intestinal or mucous membrane is not discussed in the present paper, but only the manner and degree of breaking up of ingested milk fat, and the part played in such a process by the pancreas. My former paper showed that there was a great decrease in the absorption of fat when the pancreas was removed, and it is my present purpose to show how much of this is due to the absence of either the fat-splitting ferment, or of the alkaline sodium carbonate of the pancreatic secretion.

It is not necessary here to again draw attention to the extracts from the literature of this complicated subject, which I quoted in the previous paper, and which showed that there was reason to believe that neutral fat not only could split up fat acids and glycerine in the absence of pancreatic secretion, but even form soaps. The present research has for its object the precise determination of this point.

The results obtained may therefore be divided into a normal and a pathological, *i.e.*, according as to whether the pancreatic secretion is present or absent. Thus :—

1. The normal splitting up of fat in the various parts of the alimentary canal in dogs on a milk diet.
2. The effect of removal of the pancreas on the splitting up of fat in dogs on a milk diet.

Before discussing the results, it will be as well to give briefly the method employed.

Method of Investigation.

1. *Operative Procedure.*—The animals were in all cases treated in practically the same manner. The "normal" dogs were allowed to fast for a period of four days, during which time the rectum was washed out with a copious warm water enema, glycerine being afterwards given so as to aid the expulsion of the water. In the cases where the influence of the pancreas on the breaking up of fat was to be investigated after two days' fast, the pancreas was entirely removed under ether, and then the animals allowed to fast another two days, during which time the bowels were again washed out.

A given quantity of milk was administered in the morning, and seven hours later the dogs were killed by means of chloroform. The abdomen was quickly opened, and ligatures applied to the oesophagus, the pylorus, just above the cæcum, and as low down as possible round the rectum. The contents of each part of the alimentary canal thus isolated were then carefully collected and separately analysed.

The milk given in each case was concentrated to a convenient quantity by boiling; a specimen of this was analysed, so that the

absolute composition of the fats present in the milk at the time of administration was accurately known, and could be compared with that in the various parts of the alimentary canal.

2. *The Chemical Analysis.*—The substances collected from each separate part were dried at 90° C., and then placed in a Soxhlet's apparatus and extracted with ether until the ether was unable to extract any more soluble matter. The ether extract was then dried and re-dissolved in absolute ether of sp. gr. 0·720, and filtered through a fat-free filter paper into a weighed vessel, in which it was dried and afterwards weighed.

The ether residue thus obtained was then treated with a watery solution of sodium carbonate, which converted the free fat acids into soaps, and after again drying, the neutral fat, cholesterin, &c., was again extracted with ether and weighed. The difference between this and the first weighing was taken as equal to the quantity of free fat acids present.

In some few cases quantitative estimation of the cholesterin was made by saponifying the neutral fat extract with alcoholic sodium hydrate, evaporating to dryness, and then extracting with ether. This being repeated until saponification with alcoholic sodium hydrate no longer removed any neutral fat, and it was found that the ether extract consisted of cholesterin alone.

The original substance which had been extracted with ether was treated with dilute hydrochloric acid so as to liberate any fat acids from the soaps that might be there present. It was then dried at 90° C., and when completely dry was again extracted with ether. The quantity of ether extract thus obtained represented the fat acids present in the form of soaps.

The total fat was, therefore, obtained by adding the quantity of fat acids obtained from the soaps to the former ether extract.

To facilitate the comparison of the results in the experiments they are given in tabular form, and the analysis of the diet in each part of the alimentary canal is divided into groups, *i.e.*, neutral fat, fat acids, and fat acids combined as soaps.

The neutral fat includes the cholesterin, which was not in the majority of cases separately analysed, as the quantitative analysis of cholesterin is very much more difficult in practice than it is in theory, since the entire saponification of the neutral fats, so as to separate them thoroughly from cholesterin, is a tedious matter and requires frequent repetition if one desires to get really accurate results. In those few cases in which the analysis of cholesterin was carried out, the quantity found was so extremely small that it in no way interfered with the general results obtained if the entire extract was regarded as neutral fat.

The Splitting up of Fat in various parts of the Alimentary Canal in Normal Dogs on a Milk Diet.

The following are the results obtained in normal dogs:—

Table I.—Normal Dog, weighed 6·66 kilos., killed by Chloroform Seven Hours after being fed with Milk.

| | Total ether extract. | | Neutral fat. | | Free fat acids. | | Fat acids as soaps. | |
|------------------|----------------------|-------|--------------|-------|-----------------|-------|---------------------|-------|
| | Total. | p. c. | Total. | p. c. | Total. | p. c. | Total. | p. c. |
| | | | | | | | | |
| Given..... | 9·471 | 100 | 9·456 | 99·85 | 0·012 | 0·12 | 0·003 | 0·03 |
| Found in— | | | | | | | | |
| Stomach..... | 3·503 | 100 | 2·691 | 76·82 | 0·768 | 21·92 | 0·044 | 1·26 |
| Small intestine. | 0·845 | 100 | 0·214 | 25·33 | 0·600 | 71·01 | 0·031 | 3·66 |
| Large intestine. | 0·791 | 100 | 0·296 | 37·42 | 0·445 | 56·26 | 0·050 | 6·32 |

In Table I it is seen that the total quantity of fat given is diminished in the stomach to almost a third during the seven hours of digestion, so that of the 9·471 grams of fat that had been given in the milk only 3·503 grams were found, the rest having passed through the pylorus. The composition of this fat is, however, entirely changed, for while the milk fat contained 99·85 per cent. as neutral fat, that in the stomach was only 76·82 per cent.

We see, further, that the neutral fats have disappeared from the stomach more rapidly than the others as, although 9·456 grams of neutral fat were given, only 2·691 grams remained.

The formation of free fat acids is very marked, for whereas the milk only contained 0·12 per cent. the stomach contained as much as 21·92 per cent. This speaks strongly in favour of Ogata and Marce's view that neutral fat can be broken up into free fat acids in the stomach, unless one is to believe that the fat acids had been retained in the stomach, and that the increased percentage was obtained by some condition allowing the passage of the neutral fats and not the fat acids from the stomach. But it may further be seen that this would not account for the increase in the free fat acids, as the total quantity of fat acids given was only 0·012 while the stomach contained no less than 0·768. It may, therefore, be regarded as conclusively established that the excess of fat acids was formed from the neutral fat of the milk in the stomach itself.

More remarkable is the proportion of fat acids combined as soaps. For the milk itself contained only 0·03 per cent. of fat acids in the form of soap, while the stomach contained 1·26 per cent. That there had been an absolute formation of soap and not any increase

by the mere passage of the neutral fat from the stomach is proved by the fact that the total quantity of such soaps given was only 0·003, while the stomach at the end of seven hours contained 0·044 gram.

It is thus shown beyond question that the stomach is not only capable of breaking up neutral fat into free fat acids and glycerine, but that some of these free fat acids are able to find in the gastric secretion an alkaline substance with which they can form soaps even in the acid stomach contents.

Turning next to the contents of the small intestine, we find that the total fat is very small in quantity, there only being 0·845 gram, of which 0·214 gram remain as neutral fat, so that only 25·33 per cent. of the total fat remains in the small intestine as neutral fat. Fat acids, on the other hand, are very greatly increased, 71·01 per cent. of the total fat being present as fat acids. The absolute quantity of fat acids present in the small intestine is only 0·600 gram; that is to say, really less than was present in the stomach. The percentage proportion of the soaps is also increased over that of the stomach, being 3·66 per cent., although the total quantity present is somewhat less than what was present in the stomach, being only 0·031 gram.

In the large intestine we find that the total fat is only slightly less than that present in the small intestine, being 0·791 gram. This is composed of 0·296 gram of neutral fat, that is to say, somewhat more than was present in the small intestine, and making the percentage of neutral fat present in the large intestine as much as 37·42. The free fat acids are only 0·445 gram, and the percentage is also decreased to only 56·26 per cent.; that is to say, the percentage of fat acids present in the large intestine is greater than that present in the stomach, but not so large as that present in the small intestine.

The soaps, on the other hand, are increased, being 0·050 gram, and constitute a percentage of 6·32; so that the amount of soap present in the large intestine is almost double that present in the small intestine and five times that in the stomach.

In this the second normal animal (Table II) as much as 43·13 per cent. of the total fat given had left the stomach during the seven hours' digestion, so that the stomach only contained 12·970 grams of the 22·806 grams of fat given in the milk.

On examining the composition of the total fat present in the stomach we find that it has undergone a marked change, since, of the milk fat given, no less than 96·69 per cent. was present as neutral fat, while the stomach contained 81·12 per cent., the total neutral fat having diminished from the 22·05 grams given in the milk to only 10·52 grams. Hence 15·57 per cent. of the neutral fat given had been changed into some other form during its seven hours' sojourn in the stomach.

Table II.—Normal Dog, weighed 12·825 kilos., killed by Chloroform
Seven Hours after feeding with Milk.

| | Total ether extract. | | Neutral fat. | | Free fat acids. | | Fat acids as soaps. | |
|------------------|----------------------|-------|--------------|-------|-----------------|-------|---------------------|-------|
| | Total. | p. c. | Total. | p. c. | Total. | p. c. | Total. | p. c. |
| Given..... | 22·806 | 100 | 22·050 | 96·69 | 0·744 | 3·25 | 0·012 | 0·06 |
| Found in— | | | | | | | | |
| Stomach | 12·970 | 100 | 10·522 | 81·12 | 2·436 | 18·78 | 0·012 | 0·10 |
| Small intestine. | 0·977 | 100 | 0·349 | 35·85 | 0·608 | 62·19 | 0·020 | 2·06 |
| Large intestine. | 0·402 | 100 | — | — | — | — | — | — |

As regards the free fat acids, the milk given contained 0·744 gram, *i.e.*, 3·25 per cent. of the total ether extract was obtained as fat acid, which is far more than usual, and is probably in part due to the fact that the milk stood in the laboratory for some time previously to its being boiled for the experiment.

The stomach contained 2·436 grams of fat acids, *i.e.*, 18·78 per cent. of the total fat was present in the stomach as free fat acids. The percentage of the neutral fat had diminished, while the percentage of the fat acids had increased. The fat acids, combined as soaps in the stomach, remained exactly the same as the quantity originally given, but since the percentage had increased from 0·06 to 0·10, it is not at all likely that that alone of the components of the total fat had wholly remained in the stomach, so that we may consider that this case is no exception, and that the stomach formed not only fat acids but also soap.

In the small intestine only 0·977 gram of fat was found, and since no less than 9·836 grams had passed through the pylorus during the period of digestion, either 8·859 grams had passed on into the large intestine or had been absorbed. The total fat contained only 0·349 gram as neutral fat, so that the percentage had fallen to 35·85 per cent. (the milk given contained 96·69 per cent.). The free fat acids amounted to 0·608 gram, that is 62·19 per cent. of the total fat.

As originally the milk only contained 3·25 per cent. of fat acids, we can conclude that no less than 58·94 per cent. of the neutral fat had been converted into fat acids in its passage as far as the cæcum. The fat acids present as soaps had increased to 0·02 gram, which raises the percentage of fat acids present as soaps to no less than 2·06, an amount which closely resembles that present in the foregoing case.

In the large intestine we unfortunately cannot follow the changes in this experiment, as the neutral fat and free fat acids and soaps

were lost in the process of separation. We, however, see that only 0·402 gram of the total ether extract was left in the large intestine, so that 8·457 grams of the fat had really been absorbed during the seven hours' digestion ; that is to say, as much as 85·98 per cent. of the total quantity of fat that had traversed the pylorus.

Table III.—Normal Dog, weighed 10·35 kilos., killed by Chloroform Seven Hours after feeding with Milk.

| | Total ether extract. | | Neutral fat. | | Free fat acids. | | Fat acids as soaps. | |
|------------------|----------------------|-------|--------------|-------|-----------------|-------|---------------------|-------|
| | Total. | p. c. | Total. | p. c. | Total. | p. c. | Total. | p. c. |
| Given..... | 12·027 | 100 | 11·533 | 95·89 | 0·455 | 3·78 | 0·039 | 0·33 |
| Found in— | | | | | | | | |
| Stomach..... | 8·116 | 100 | 6·061 | 74·67 | 2·012 | 24·81 | 0·043 | 0·52 |
| Small intestine. | 0·623 | 100 | 0·080 | 12·84 | 0·522 | 83·46 | 0·021 | 3·70 |
| Large intestine. | 0·741 | 100 | 0·229 | 30·91 | 0·452 | 61·03 | 0·059 | 8·06 |

In Table III the total fat given was 12·027 grams, and after seven hours' digestion 8·116 grams remained in the stomach. The stomach had consequently discharged 3·911 grams of the fat into the intestines (*i.e.*, 32·52 per cent.).

The fat that remained in the stomach during the seven hours had undergone similar changes to those already described in the former two experiments. The neutral fat had decreased from 11·533 grams in the milk given to 6·061 grams. Thus, while the milk fat contained 95·89 per cent. as neutral fat, the stomach only contained 74·67 per cent., so that at least 21·22 per cent. of the neutral fat given had been split up in the stomach into free fat acids or traversed the pylorus.

The free fat acids on the other hand had increased very markedly ; for whereas the milk contained but 0·455 gram the stomach contained 2·012 grams, the percentage composition having thus changed from 3·78 to 24·81.

The soap had also increased in quantity in the stomach from 0·039 gram, in the milk given, to 0·043 gram, which altered the percentage composition from 0·33 to 0·52 per cent.

Thus, in all three experiments we have confirmation of the fact that neutral fat is split up into free fat acids while in the stomach itself, and that some of these free fat acids formed soaps.

With regard to the small intestines we find only 0·623 gram of ether extract was present, while we know that 3·91 grams had

passed through the pylorus during this time. Of the total fat only 0·080 gram was found as neutral fat, so that its percentage proportion amounted to only 12·84 per cent., no less than 61·83 per cent. of the neutral fat having been broken up since it traversed the pylorus.

The free fat acids increased to 0·522 gram, therefore the percentage of the total fat present as fat acids was 83·46. As originally only 3·78 per cent. of the total fat was in the form of free fat acids, therefore 79·68 per cent. of the neutral fat has been broken up into free fat acids in its passage along the stomach and small intestine, and as the stomach contained 24·81 per cent., therefore 55·87 per cent. of the free fat acids had been formed in the small intestine.

The quantity of fat acids present as soap in the small intestine was only 0·021 gram, but the total quantity of fat being so small the percentage was 3·70.

It would thus appear as if 2·37 per cent. of the ether extract had been converted into soap in its passage from the mouth to the cæcum, and since 0·19 per cent. was found in the stomach, 2·18 per cent. had been formed in the small intestine.

The large intestine contained 0·741 gram of total fat, of which 0·229 gram remained in the form of neutral fat, and the percentage of the neutral fat was 30·91, *i.e.*, somewhat higher than that found in the small intestine, although less than half the percentage in the stomach. The free fat acids left in the large intestine were 0·452 gram, *i.e.*, 61·03 per cent. of the total ether extract present, the quantity is therefore less than is present in the small intestine, but higher than that in the stomach.

The fat acids combined as soap in the large intestine were 0·059 gram, so that the percentage was 8·06 of the total fat.

With regard to the absorption of fat, in this case we see that where 12·027 grams were given only 9·479 were regained after seven hours' digestion, so that at least 2·548 grams had been absorbed, *i.e.*, 21 per cent. of the total given during the seven hours' digestion. However, as no fat is probably absorbed from the stomach, we ought only to calculate the percentage absorption from the 3·911 grams which had passed into the small intestine, *i.e.*, 65·16 per cent. of this had been absorbed.

The Splitting up of Fat in various parts of the Alimentary Canal in Dogs on a Milk Diet and in which the Pancreas had been removed.

Having shown the manner in which fat is broken down in the intestines of dogs under normal circumstances, we can now consider the changes that occur in the fats when milk is given to dogs in which the pancreas has been previously removed.

In the following experiments, as has been already said, the pancreas was removed on the second day of fasting, and the animals allowed to fast still further two days after the operation, the rectum being washed out with copious warm water enemas, as by this means it was hoped to rid the intestines of any residue of pancreatic secretion which might otherwise be present, and at the same time that the washing out would diminish the bacteria of the large intestine to a considerable extent.

In the four following dogs in no case was there, by analysis, any evident absorption of fat from the intestines during the space of four to seven hours. At the same time, the fact that the quantity of fat found equalled or surpassed the quantity of fat given at the end of this time, is no definite proof that no absorption of fat took place from the large intestine. In all probability there was some absorption, as the lymphatics shone out as white lines and had not the appearance of those normally present in fasting animals, though they were not so prominent or filled as was the case in normal dogs during the same period of digestion. The remarkable fact that the quantity of fat was equal to, or in excess of, that given will appear to be explained by the character of the intestinal excretion, or so-called secretion, which has now been practically demonstrated to be always present by Hermann, Ehrenthal, Berenstein, and Fr. Voit, which is in all probability a substance rich in fat and very much more profuse than we are ordinarily led to believe.

Table IV.—Weight, 6·19 kilos. Total Extirpation of Pancreas. Dog being given Milk forty-eight hours after Removal of Gland and killed by Chloroform four hours after the Diet.

| | Total ether extract. | | Neutral fat. | | Free fat acid. | | Fat acids as soap. | |
|------------------|----------------------|-------|--------------|-------|----------------|-------|--------------------|-------|
| | Total. | p. c. | Total. | p. c. | Total. | p. c. | Total. | p. c. |
| Given..... | 7·602 | 100 | 7·350 | 96·68 | 0·248 | 3·26 | 0·004 | 0·06 |
| Found in— | | | | | | | | |
| Stomach | 7·406 | 100 | 4·513 | 60·94 | 2·727 | 36·82 | 0·166 | 2·24 |
| Small intestine. | 1·456 | 100 | 0·820 | 31·17 | 0·452 | 56·55 | 0·184 | 12·48 |
| Large intestine. | 0·444 | 100 | 0·159 | 35·81 | 0·271 | 61·04 | 0·014 | 3·15 |

In Table IV the total quantity of fat given was 7·602 grams, and after the period of four hours, no less than 7·406 grams still remained in the stomach, so that during four hours only 0·196 gram had entered the intestines, or but 2·58 per cent. of the quantity

given had passed through the pylorus. Further, since the small and large intestines contained no less than 1·902 grams, while only 0·196 gram of this had entered from the pylorus, at least 1·704 grams of this fat must be regarded as derived directly from the intestinal secretion and not from the fat administered in the food. Of course, in this case, the fat might be partly derived from the bile, as, although the pancreas had been entirely removed, the bile-ducts had been in no way interfered with. The fact that the dog had not only fasted for four days but that it had had its bowels washed out daily, would leave little doubt that this fat could not be residues of fat given five days previously.

In investigating the various changes that the fat underwent during its sojourn in the stomach, only 4·513 grams were found as neutral fat; that is to say, 60·94 per cent. of the total fat still remained as neutral fat. The milk contained, on the other hand, 96·68 per cent. as neutral fat, so that no less than 25·74 of the fat given had been split up during its four hours' sojourn in the stomach into free fat acids and glycerine. The fat acids were increased to 2·727 grams, and this was no doubt due to the splitting-up of the neutral fat in the stomach, since only 0·248 gram fat acids were given in the diet. The percentage of fat acids present in the stomach being 36·82, the quantity found in the viscera was ten times the amount present in the milk given.

As regards the soap, it was increased to 0·166 gram, so that the percentage composition of the fat acids combined as soaps was 2·24 as compared to the 0·06 per cent. of fat acids (combined as soaps) observed in the milk.

From these facts it is plain that even after the removal of the pancreas the stomach, as in normal dogs, is capable of converting a considerable quantity of the neutral fat into fatty acids, and still further forming soaps.

The small intestine contained 1·456 grams of fat, and, as has already been said, most of this was not derived from the milk given but partly from the excretion of the intestines; however, it will be as well to examine its chemical composition in the same way as we have done in the normal dogs.

Of this fat, 0·820 gram was found to be neutral fat, so that the percentage of neutral fat was 31·17. The free fat acids were 0·452 gram, the total quantity being increased to 56·55 per cent., and the soap had increased to 12·48 per cent., the total quantity really being 0·184 gram.

We see that the quantity of fat acids had very much increased in the small intestine over that found in the stomach, even although no pancreatic secretion was present.

In the large intestine the total quantity of fat present was only

0·444 gram, and of this 0·159 gram only remained as neutral fat. The free fatty acids were only 0·271 gram, the percentage being no less than 61·04, showing that the percentage of fat acids was greater in the large intestine than either in the small intestine or in the stomach.

The soaps had fallen to only 0·014 gram, or 3·15 per cent., so that they were really smaller than the quantity in the large intestine, but larger than that in the stomach.

Table V.—Weight, 6·98 kilos. Total Extirpation of the Pancreas.
Milk Diet forty-eight hours after Removal of the Gland, and
killed by means of Chloroform six hours later.

| | Total ether extract. | | Neutral fat. | | Free fat acids. | | Fat acids as soap. | |
|------------------|----------------------|-------|--------------|-------|-----------------|-------|--------------------|-------|
| | Total. | p. c. | Total. | p. c. | Total. | p. c. | Total. | p. c. |
| Given..... | 8·496 | 100 | 7·134 | 83·98 | 1·352 | 15·91 | 0·008 | 0·09 |
| Found in— | | | | | | | | |
| Stomach | 7·624 | 100 | 4·964 | 65·11 | 2·573 | 33·75 | 0·087 | 1·14 |
| Small intestine. | 0·822 | 100 | 0·312 | 37·95 | 0·452 | 54·99 | 0·058 | 7·06 |
| Large intestine. | 0·251 | 100 | 0·082 | 32·68 | 0·113 | 45·01 | 0·056 | 22·31 |

In Table V the animal was allowed to digest for six hours after the feeding. In this case the total fat given was 8·496 grams, while after six hours' digestion the stomach still contained 7·624 grams; hence only 0·872 gram of the fat had passed through the pylorus into the intestines in this space of time.

In the small and large intestines 1·073 grams were collected, so that 0·201 of this must have been due to the excretion from the intestinal wall or derived from the bile.

The stomach contained only 4·964 grams of its fat as neutral fat, and whereas the milk given contained 83·98 per cent. of its fat as neutral fat, the stomach only contained 65·11 per cent. This was due to the increase of free fat acids for the most part, but also to some extent to the formation of soaps. The free fat acids present in the stomach were 2·573 grams, while the original milk only contained in all 1·352 grams, therefore 33·75 per cent. of the total fat was present in the stomach as free fat acids.

The soaps also had increased in quantity. The stomach contained 0·087 gram, while the milk given only contained 0·008, the percentage of fat acids present as soaps being thus raised to 1·14.

It is clearly brought out in this experiment that there was a very

great delay in the quantity of fat leaving the stomach during the six hours, as compared with what was observed in the normal dogs.

In the small intestine the total fat present was only 0·822 gram. This is somewhat less than what we know has already passed through the pylorus, for it was seen that 0·872 gram of fat had left the stomach during the six hours. The neutral fat in the intestine was only 0·312 gram, so that the quantity had diminished to only 37·95 per cent., a little more than half of that present in the stomach.

The quantity of free fat acids was 0·452 gram, the percentage having increased to 54·99, almost double what was present in the stomach. The fat acids present as soaps were 0·058 gram, bringing the percentage composition of the soap to 7·06.

The large intestine contained 0·251 gram of fat; of this, a very great part must be attributed to the intestinal excretion, and was certainly not residue of the fat given. The neutral fat is only 0·082 gram, that is to say, 32·68 per cent. of the total fat only remains as neutral fat when it has reached as far as the large intestine.

The free fat acids amounted to 0·113 gram, so that the percentage proportion was 45·01, this being less than that present in the small intestine.

The soap present was 0·056 gram, the total quantity being almost the same as that present in the small intestine, but as the quantity of total fat is very much smaller, the relative amount of fat acids combined as soaps reaches in the large bowel a very much higher point than in any other part of the alimentary canal, being 22·31.

In the next two dogs in which the pancreas was removed the period of digestion allowed was seven hours in each case.

Table VI.—Weight, 5·40 kilos. Total Extirpation of the Pancreas.
Milk given forty-eight hours after Removal of the Gland.
Killed by Chloroform after seven hours' digestion.

| | Total ether extract. | | Neutral fat. | | Free fat acids. | | Fat acids as soap. | |
|------------------|----------------------|-------|--------------|-------|-----------------|-------|--------------------|-------|
| | Total. | p. c. | Total. | p. c. | Total. | p. c. | Total. | p. c. |
| Given..... | 7·191 | 100 | 6·877 | 95·63 | 0·309 | 4·30 | 0·005 | 0·07 |
| Found in— | | | | | | | | |
| Stomach..... | 6·554 | 100 | 2·708 | 41·32 | 3·828 | 58·41 | 0·018 | 0·27 |
| Small intestine. | 1·077 | 100 | 0·470 | 43·64 | 0·561 | 52·09 | 0·046 | 4·27 |
| Large intestine. | 0·644 | 100 | 0·175 | 27·17 | 0·359 | 55·75 | 0·110 | 17·08 |

In the above Table VI, of 7·191 grams of fat given no less than 6·554 still remained in the stomach, so that only 0·637 gram had

traversed the pylorus. The small and large intestines together contained no less than 1·721 grams of fat, and therefore 1·084 grams of the fat had been excreted from the intestines or liver during the period of seven hours. This appears an enormous quantity when we compare it with the small amount in the case of Table V, in which only 0·201 gram was excreted in six hours.

The stomach contained 2·708 grams of neutral fat remaining from the 6·877 grams of the neutral fat given in the milk. Thus the percentage of neutral fat found was 41·32, while the neutral fat in the milk given was no less than 95·63; hence 58·41 per cent. of the neutral fat given had been split up into fat acids during seven hours in the stomach.

The quantity of free fat acids was 3·828 grams, and the soaps had increased to 0·018 gram, this constituting a percentage of 0·27.

The small intestine gave as the percentage of neutral fat 43·64, as compared with 41·42 present in the stomach.

This is a very different thing to what is found in the case of the normal dogs, where the fat acids in the small intestine were greatly increased and the neutral fat much diminished, for here the free fat acids were only 52·09 per cent., i.e., very slightly above the amount of neutral fat present in the small intestine, and less than the fat acids present in the stomach. The small intestine also contained no less than 4·27 per cent. of fat acids in the form of soap.

In the case of the large intestine the total quantity of fat present was 0·644; of this, 0·175 still remained as neutral fat, the percentage being 27·17, while 55·75 per cent. was present in the form of free fat acids, and 17·08 per cent. of the fat acids had combined to form soaps.

Table VII.—Weight, 6·70 kilos. Total Extirpation of the Pancreas.

Milk given forty-eight hours after Removal of the Gland, and killed by Chloroform after seven hours' digestion.

| | Total ether extract. | | Neutral fat. | | Free fat acids. | | Fat acids as soap. | |
|------------------|----------------------|-------|--------------|-------|-----------------|-------|--------------------|-------|
| | Total. | p. c. | Total. | p. c. | Total. | p. c. | Total. | p. c. |
| Given..... | 12·027 | 100 | 11·533 | 95·90 | 0·455 | 3·78 | 0·039 | 0·32 |
| Found in— | | | | | | | | |
| Stomach | 9·358 | 100 | 9·177 | 98·07 | 0·159 | 1·70 | 0·022 | 0·23 |
| Small intestine. | 0·464 | 100 | 0·075 | 16·17 | 0·361 | 77·79 | 0·028 | 6·04 |
| Large intestine. | 1·672 | 100 | 0·663 | 39·95 | 0·990 | 59·21 | 0·014 | 0·84 |

In Table VII the dog received a larger quantity of fat than usual, and whether in consequence of this or through some other

reason, there was, towards the end of the seven hours' digestion diarrhoea which necessitated the collecting of some of the faeces passed, and by reason of this there was a possibility of some slight loss.

This case alone, of all the dogs in which the pancreas was removed, indicated any absorption of fat, for out of the 12.027 grams of the fat given 0.533 gram was not recovered. It was, however, perfectly obvious that in this experiment this deficit was attributable to loss in collection of the faeces, although everything to hinder such an error was attempted.

The stomach contained 9.358 grams of fat, of this no less than 9.177 grams was in the form of neutral fat. In fact, 98.07 per cent. of the total fat was present in this case as neutral fat, while the milk given contained only 95.90 per cent.

The free fat acids in the milk given contained 0.455 gram, while in the stomach only 0.159 gram was found; that is to say, 1.70 per cent. of the total fat only was present as fat acids in the stomach. Soaps also were 0.022 gram, and the percentage 0.023.

In this dog alone, of either the normal dogs or those in which the pancreas was removed, was there no indication of breaking up of neutral fat into free fat acids in the stomach, as far as the total quantity of fat acids found in the stomach was concerned. The explanation of this is very difficult. It may be due to the fact that the milk fat in this case had very considerably broken up before it was administered, the milk being somewhat acid, and it had been boiled down considerably in order to decrease the volume given. The quantity of fat which had left the stomach during the seven hours' digestion was no less than 22.19 per cent. of the total given, that is, much more than occurred in any of the other dogs in which the pancreas had been previously removed. In fact, this out-flow is more like the normal dogs. It is, therefore, possible that the soaps and fat acids which had been formed in the stomach had to a considerable extent left it, and if to a greater extent than the neutral fat had thus caused the percentage of neutral fat to be higher than that given.

The quantity of fat in the large gut was more than in the small intestine, and this also was exceptional, as in all the other cases the reverse was found after seven hours, and it can be only explained by the fact that on account of the milk being sour and the diarrhoea which occurred, there was a hurrying along of the contents of the alimentary canal.

The quantity of fat in the small intestine was only 0.464 gram, of which 0.075 gram was present as neutral fat; that is to say, only 16.17 per cent. of the total fat was present in the stomach as neutral fat. The fat acids on the other hand were no less than 0.361 gram, that is 77.79 per cent. of the total fat present in the small intestine.

This result may not be due entirely to the breaking up of the fat in the small intestine, but to the increased out-put of fat acids from the stomach. The soaps equalled 6·04 per cent. of the total fat present in the small intestine, although the actual quantity was only 0·028 gram.

In the large intestine the quantity given in the table was not only that which was present in the intestine after death, but also that which was collected in the faeces, passed during the last hour or so of life. It contained 1·672 grams of fat, of which 0·668 gram were in the form of neutral fat, and 0·990 had been broken up into free fat acids. So that 59·21 per cent. of the total fat was in the form of fat acids, and 39·95 per cent. only as neutral fat.

The soaps were not very much increased, the total quantity being only 0·014, that is to say 0·84 per cent.

Summary.

When we come to compare the results found in the normal dogs during the absorption of milk fat with that in the dogs in which the pancreas has been removed, we see that there is not such a great difference as one would be led to suspect by the old teaching of the fat splitting action of the pancreas.

For the purpose of comparison it will be better to tabulate the average results of the preceding experiments so that the normal results may be more readily compared with those in which the pancreas had been previously removed. In this way it is easy to detect any real difference in the percentage quantities in the alimentary canal.

Table VIII.—Comparing the Percentage Composition of the Fats in the Different Parts of the Alimentary Canal on a Milk Diet, of Normal Dogs (A) with those in which the Pancreas (B) had been previously removed.

| | Neutral fat. | | Free fat acids. | | Fat acids as soap. | |
|---------------------|---------------|-----------------|-----------------|-----------------|--------------------|-----------------|
| | Normal. A. | Pancreas. B. | Normal. A. | Pancreas. B. | Normal. A. | Pancreas. B. |
| Stomach | 77·54 | 68·17 | 18·50 | 31·29 | 0·63 | 0·55 |
| Small intestine.... | 24·67 | 32·59 | 72·22 | 61·62 | 3·14 | 5·79 |
| Large intestine.... | 34·17 | 33·27 | 58·65 | 53·32 | 7·19 | 13·41 |

The average number of cases in the above Table VIII is three in each column, except in that of the large intestine of the normal dogs,

in which the results of only two experiments were used, and the period of digestion was seven hours, except in one case of removal of the pancreas in which it was only six hours.

As far as the stomach is concerned, the table shows that there is a slight increase in the quantity of fat acids in dogs in which the pancreas has been removed, as the percentage noted was 31.29 per cent. of the total fat, while in the normal dogs which were employed as control, only 18.50 per cent. of the total fat was present in the form of free fat acids. This would be in favour of a greater fat splitting-up activity of the stomach in dogs in which the pancreas had previously been removed. That a greater splitting-up action was really the cause of this increase is difficult to believe. It would seem much more likely that the increased percentage of fat acid in the dogs without the pancreas was due to the greater retention of fat in the stomach, for in all cases in which the pancreas had been removed, the expulsion of fat from the stomach was very much delayed.

The percentage quantity of fat acids present as soap in both the normal and the pathological dogs is practically equal, for in both cases no less than 0.63 and 0.55 per cent. of the free fat acids were present as soap in the stomach.

The table therefore proves that both in normal dogs as well as in those in which the pancreas has been removed, the stomach is capable of not only splitting up neutral fat into free fat acids and glycerine, but further, that the free fat acids are capable of finding alkalis in the stomach itself wherewith to form soaps. The power of the free fat acids forming soap is, however, extremely limited in the stomach.

The principal fat-splitting action really begins, not in the stomach, but after it has left the pylorus. That this should be the case in normal dogs has long been held by all physiologists, and was considered due to the action of the pancreas, and the degree to which this occurs is shown in the table, according to which in the normal dog at least 72.22 per cent. of the fat present in the small intestine was in the form of free fat acids, only 24.67 per cent. being present as neutral fat. But also in the case where the pancreas had been entirely extirpated, so that no pancreatic juice could possibly reach the intestine, and the fasting had been sufficiently long to remove any pancreatic ferments which might have been previously present in the intestines, we still find a large increase in the quantity of the fat acids present, the fat acids being no less than 61.62 per cent. of the total fat. There can be no doubt, therefore, that even when no pancreatic secretion has reached the intestines, a very considerable quantity of the neutral fat is split up into free fat acids in the small intestine, although the quantity there formed is not so great as when the pancreatic secretion has been able to add its share of work.

The free fat acids combined with soaps in the normal dog were only 3·14 per cent. of the total fat present, while those dogs in which the pancreas had previously been removed had no less than 5·79 per cent.

This is a most interesting fact, for in spite of the absence of the alkaline pancreatic secretion, it is found that not only nearly the normal quantity of free fat acids are present, but a considerable increase of fat acids have formed soaps, so that the intestines have been able to secrete a sufficiency of alkali substances to form soaps.

The contents of the large intestine in the second group of cases resemble each other far more closely. In fact, in the case of the free fat acids, the quantity present in both the normal control dogs and those in which the pancreas had previously been removed is, for all practical purposes, equal, the control dogs having 58·65 per cent. of fat, in the form of free fat acid, while those dogs in which no pancreatic secretion had reached the intestines, 53·32 per cent. The effect of the want of pancreatic secretion, although exhibited to a small extent in the small intestine, and causing a diminution in the quantity of fat acids present, was no longer apparent in the large intestine.

The quantity of fat acids present as soaps in the large intestine varies, although not to a greater extent than was the case in the small intestine. Those dogs in which the pancreas had been previously removed contained 13·41 per cent. of the total fat in the form of fat acids combined as soaps, while 7·19 per cent. only was in this form in those dogs which were used as control experiments.